AFRRI TN71-7
DECEMBER 1971

AFRRI
TECHNICAL
NOTE

REACTOR DOSIMETRY WITH PAIRED MINIATURE IONIZATION CHAMBERS

D. W. Shosa

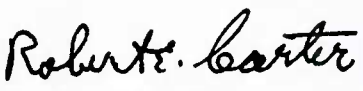
ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE
Defense Nuclear Agency
Bethesda, Maryland

AFRRI TN71-7

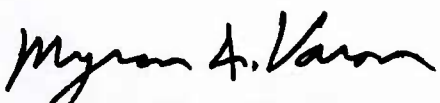
AFRRI TN71-7
December 1971

REACTOR DOSIMETRY WITH PAIRED MINIATURE IONIZATION CHAMBERS

D. W. SHOSA



R. E. CARTER
Chairman
Physical Sciences Department



MYRON I. VARON
Captain MC USN
Director

ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE
Defense Nuclear Agency
Bethesda, Maryland

ACKNOWLEDGMENT

The author is indebted to D. M. Verrelli for project guidance; to C. Carter and C. L. Bransford for experimental assistance; to the staff of the Reactor Division; and to R. E. Carter, B. E. Leonard and H. O. Wyckoff for help in editing the manuscript.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Paired ionization chambers with nominal volumes of 0.05 cm^3 are in use at the Armed Forces Radiobiology Research Institute to measure neutron and gamma components of depth doses in steady-state and pulsed TRIGA fields. Cavity chamber theory is employed to obtain quantitative estimates of neutron and gamma dose sensitivities of a chamber with a tissue-equivalent plastic wall filled with a tissue-equivalent gas and a magnesium chamber filled with CO_2. The uncertainties in these estimates have been propagated through the paired chamber equations and result in the following uncertainties in measured dose components in a field where the neutron to gamma dose ratio varies from 0.1 to 15

Total dose $\pm$ 8 percent
Gamma dose $\pm$ 20 percent ($N/\Gamma \lesssim 0.1$) to $\pm$ 30 percent ($N/\Gamma \gtrsim 10$)
Neutron dose $\pm$ 8 percent ($N/\Gamma \gtrsim 10$) to $\pm$ 12 percent ($N/\Gamma \sim 0.1$).

I. INTRODUCTION

When biological specimens are exposed to the radiations of a nuclear reactor, there is a minimum amount of information necessary to characterize the exposure. Because the biological effects of neutron and gamma ray interactions with tissue may be different, the specification of total kerma at a point in the field, or even total absorbed dose at points of interest within the specimen, provides only an incomplete picture. To correlate data from different exposures, information on the separate neutron and gamma components of the total absorbed dose at points within the specimen is usually essential. Further, in situations where biological damage depends on the dose rates, the dosimetry must measure those rates. The dosimetry characteristics required to support radiobiological experiments in the reactor environment must:

(a) have a dose rate range extending from a few rads per minute to approximately 10^6 rads per minute,

(b) be sufficiently small so that perturbation of the radiation field is minimal and so that depth-dose profiles may be determined in phantoms and cadavers,

(c) be able to accurately determine the tissue dose delivered by reactor neutrons for the range of neutron energies extending from those in an unmoderated fission spectrum to those in moderated spectra which exist in the interior of large animal specimens, and

(d) be able to determine the gamma ray contribution to the tissue dose.

The purpose of this paper is to describe a paired chamber dosimetry system, consisting of tissue-equivalent (TE) and "neutron-insensitive" ionization chambers,

which satisfies the above requirements. A specific application to depth-dose profile determination in a miniature pig cadaver has been discussed by Verrelli and Shosa.[12]

II. MATERIALS AND METHODS

A diagram of a 0.05 cm^3 ionization chamber, designed by Wyckoff and Shonka,[6] is shown in Figure 1. This total dose sensitive TE chamber is made of tissue-equivalent plastic (Shonka A-150) and filled with tissue-equivalent gas, the compositions of which are shown in Table I. The "neutron-insensitive" chamber is made of magnesium and filled with CO_2. The gas is introduced through surgical tubing and a #28 hypodermic needle, and exits through a hole located on the opposite side of the antenna from the entrance needle. Because it is difficult to maintain small, uniform, reproducible flow rates, the chambers are placed in cylindrical Lucite jackets, purged with gas, and a gas flow of 100-200 cm^3/min is continued through the jackets. The flow through the chambers is stopped after purging is complete. In depth-dose distribution measurements, the jackets also serve to insulate wet tissue from the high voltage applied to the chambers and, for free-in-air measurements, they help to produce charged particle equilibrium in the chamber walls.

A Microdot signal lead carries the radiation-induced chamber current to a precision variable-gain amplifier and then to a digital voltmeter. For dosimetry in pulsed fields, the total charge collected during the pulse is given by the product of the voltage and the amplifier capacitance. For steady-state dosimetry, the readout system integrates for a preset time and the total charge collected is divided by the time interval to determine the charging rate, which is related to the dose rate. In both steady-state and pulsed modes of operation, measurements are made in pairs, one

with positive and one with negative high voltage applied to the outer wall of the chamber. The average of the magnitudes of the two measurements is taken to be the magnitude of the charge collected by the chamber. The averaging process is necessary to eliminate polarity-independent, radiation-induced signals in the Microdot leads (the chamber current polarity changes with the polarity of applied high voltage).

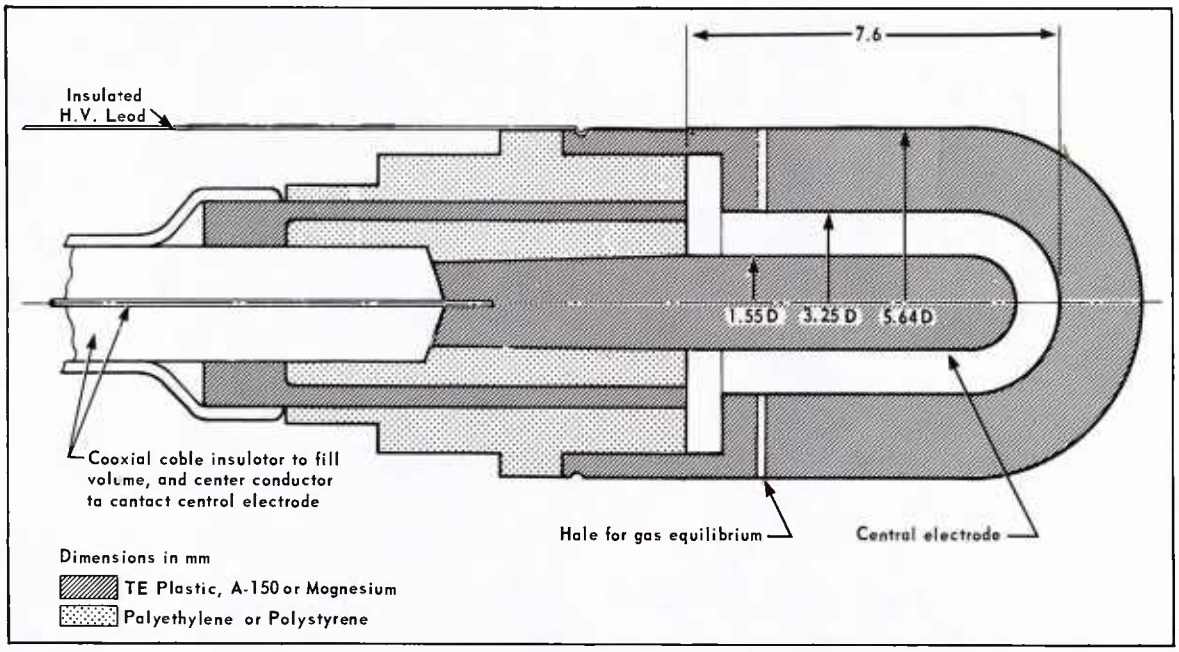


Figure 1. Section of 0.05 cm^3 ionization chamber

Atomic species	Mass fraction	
	Gas	Plastic
H	0.101	0.103
C	0.457	0.774
N	0.034	0.035
O	0.408	0.040
F		0.024
Ca		0.025

Table I. Compositions of Tissue-Equivalent Gas and Tissue-Equivalent Plastic

III. THE ANALYSIS OF CHAMBER RESPONSE

The paired chamber technique for separation of neutron and gamma absorbed dose components is discussed by several authors.[2,5,9,10] The basic principle is that the radiation-induced charge in a chamber is made up of one component which is linear with the neutron tissue dose and another component which is linear with the gamma tissue dose. The response equation is then

$$Q = \zeta kN + \eta a\Gamma \tag{1}$$

where Q is the charge produced by radiation within the chamber when exposed simultaneously to a neutron dose of N rads and a gamma dose of Γ rads, k and a are neutron and gamma ray sensitivity coefficients, and ζ and η are neutron and gamma attenuation corrections. To minimize uncertainties associated with the sensitive volumes of the chambers, which are difficult to determine independently, all charges are normalized to a unit of charge equal to the charge measured by the chamber when exposed to 1 R of gamma rays. ^{60}Co or ^{137}Cs gamma rays are used for this calibration. Each of the chambers has a response governed by an equation of the form of equation (1), and when the chambers are exposed simultaneously the response equations may be solved simultaneously to obtain N and Γ

Voltage-response characteristics in a variety of gamma and mixed neutron-gamma fields show that both chambers are operating in plateaus with 500 volts of either polarity applied to the outer electrode.

When the energy spectrum in the calibration field is similar to that of the gamma component of the mixed field, the gamma sensitivity coefficient, a, is 1.04.[9] For the TE chamber this condition is satisfied for either a ^{60}Co or ^{137}Cs calibration. For

the magnesium chamber, however, a low-energy gamma component in the mixed field will cause the gamma sensitivity coefficient to be higher than 1.04. Based on the results of experiments by Bruce and Pearson[4] and by the author, one concludes that a gamma sensitivity coefficient of 1.09 ± 0.05 for the magnesium chamber should provide sufficient latitude to cover the environments encountered in animal irradiations at our facility.

The perturbation of the absorbed dose inside a mass of tissue due to the Lucite jacket and the chamber is less than 0.5 percent. This small perturbation is due to slightly different transport properties of Lucite and tissue and to the small mass of solid displaced by the gas in the cavity. For depth-dose distribution measurements, then, $\bar{3}$ and η are very near unity. For free-in-air kerma measurements, perturbation corrections are estimated for the gamma component of the field with equilibrium cap measurements in ^{60}Co and ^{137}Cs gamma fields. Neutron attenuation corrections are calculated in a manner similar to that used by Neary et al.[10] A summary of the perturbation corrections for free-in-air measurements is shown in Table II.

Table II. Perturbation Corrections for Free-in-Air Measurement of Tissue Kerma (Lucite probe included)

Chamber	$\bar{3}$	η
TE	0.90	0.96
Mg	0.95	0.98

The neutron sensitivity coefficient of the TE chamber is determined by application of the Bragg-Gray cavity chamber theory for homogeneous chambers.[1] To estimate the neutron sensitivity of the Mg-CO_2 chamber, a comparison for a variety

of reactor fields was made with a 50 cm^3 graphite-CO_2 chamber. The neutron sensitivity of the graphite-CO_2 chamber was estimated with the application of homogeneous cavity theory. Neutron sensitivity coefficients are displayed in Table III.

Table III. Estimates of Neutron Sensitivity Coefficients

Chamber	k
TE	0.98
Graphite-CO_2 (50 cm^3)	0.08
Mg-CO_2 (0.05 cm^3)	0.07

Estimates of the systematic errors associated with the measurement of charges and estimates of sensitivity coefficients are shown in Figure 2. These arise from the following estimates of systematic error components:

(a) An estimated uncertainty of $\pm$ 3 percent for the neutron sensitivity coefficient of the TE chamber arises as a result of an energy dependence of W for heavy recoils.[3,8,11]

(b) An estimated uncertainty of $\pm$ 10-15 percent for the Mg chamber neutron sensitivity arises as a result of the energy dependence of W for heavy recoils and also as a result of an energy dependence of the mass energy transfer coefficients of Mg and CO_2 for neutrons relative to that of tissue.[7]

(c) An estimated uncertainty of $\pm$ 5 percent of the gamma sensitivity of the Mg chamber arises as a result of a low-energy component in the gamma component of the mixed field.

(d) An estimated uncertainty of $\pm$ 1 percent is associated with the charge measurement process.

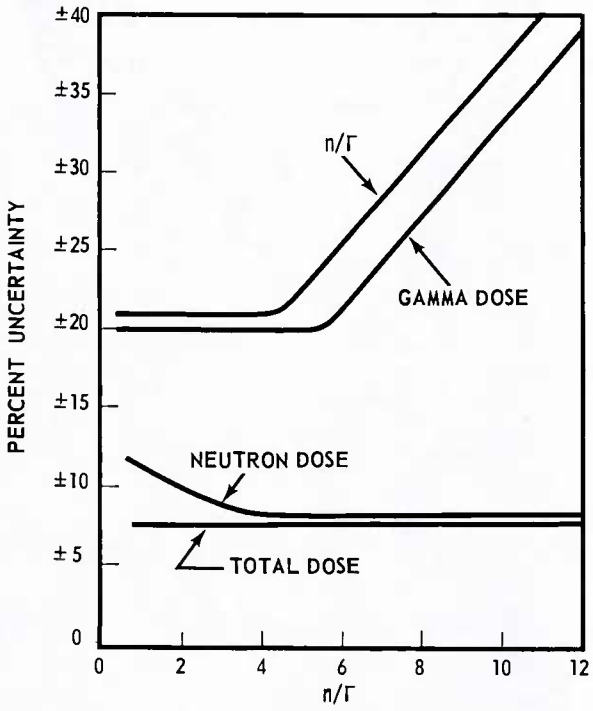


Figure 2. Uncertainty in separated neutron and gamma doses

IV. RESULTS

Comparison of the separated neutron and gamma, free-in-air, tissue kerma in a steady-state mixed field as measured by the miniature chambers described here and as measured by 50 cm^3 TE-TE and graphite-CO_2 chambers is shown in Tables IV and V.

The differences observed in the comparison might be attributed to uncertainty in defining a "point" in the field with the 50 cm^3 chambers and to different systematic errors associated with the two paired chamber systems.

Table IV. Comparison of Gamma Kerma Rate Measured with 50 cm^3 and 0.05 cm^3 Paired Chambers (25 kW, enhanced neutron field[12])

Distance from core (cm)	Kerma rate (rads/min)	
	50 cm^3	0.05 cm^3
100	12.8	12.0
120	12.9	12.3
150	12.7	12.7
200	11.4	11.3
250	10.8	11.0

Table V. Comparison of Neutron Kerma Rate Measured with 50 cm^3 and 0.05 cm^3 Paired Chambers (25 kW, enhanced neutron field[12])

Distance from core (cm)	Kerma rate (rads/min)	
	50 cm^3	0.05 cm^3
100	152	138
120	96	90
150	61	59
200	31	31
250	21	21

V. SUMMARY AND CONCLUSIONS

A paired chamber dosimetry system has been described which shows promise of satisfying the requirements stated above for radiobiology experiments in reactor environments. The system will be useful for a wide variety of reactor environments in which the neutron dose is significant. Applications to mixed field environments in which the gamma component contains an uncertain low-energy contribution to tissue dose may involve large systematic errors.

REFERENCES

1. Attix, F. H., Roesch, W. C. and Tochilin, E., editors. Radiation Dosimetry, 2nd ed., Vol. I. New York and London, Academic Press, 1968.

2. Attix, F. H., Roesch, W. C. and Tochilin, E., editors. Radiation Dosimetry, 2nd ed., Vol. III. New York and London, Academic Press, 1969.

3. Boring, J. W. Charlottesville, Virginia, University of Virginia (unpublished data).

4. Bruce, W. R. and Pearson, M. L. Spectral distribution of scattered radiation in a water phantom irradiated with cesium-137 gamma rays. Radiation Res. 17:555-572, 1962.

5. International Commission on Radiological Units and Measurements (ICRU) Report 10b, 1962. Physical aspects of irradiation. National Bureau of Standards Handbook No. 85. Washington, D. C., U. S. Government Printing Office, 1964.

6. Kuritzky, C. S., Shonka, F. R., Wyckoff, H. O. and Pfeiffer, W. F. A miniature tissue-equivalent ionization chamber for pulse dosimetry. Bethesda, Maryland, Armed Forces Radiobiology Research Institute Technical Note TN68-9, 1968.

7. Leonard, B. E. Neutron fluence-to-kerma factors and mass energy transfer coefficients in moderated and unmoderated neutron fields. Bethesda, Maryland, Armed Forces Radiobiology Research Institute (unpublished data).

8. Lindhard, J., Nielsen, V., Scharff, M. and Thomsen, P. V. Integral equations governing radiation effects. Kgl. Danske Videnskab. Selskab, Mat.-Fys. Medd. 33(10):1-42, 1963.

9. National Committee on Radiation Protection and Measurements (NCRP) Report 25, 1960. Measurement of absorbed dose of neutrons, and of mixtures of neutrons and gamma rays. National Bureau of Standards Handbook 75. Washington, D. C., U. S. Government Printing Office, 1961.

10. Neary, G. J., Munson, R. J. and Mole, R. H. Chronic Radiation Hazards. New York and London, Pergamon Press, 1957.

11. Phipps, J. A., Boring, J. W. and Lowry, R. A. Total ionization in argon by heavy ions of energies 8 to 100 keV. Phys. Rev. 135A:A36-A39, 1964.

12. Verrelli, D. M. and Shosa, D. W. Comparison of dose patterns in a miniature pig exposed to neutron and to gamma radiation. Bethesda, Maryland, Armed Forces Radiobiology Research Institute Technical Note TN71-5, 1971.

DISTRIBUTION LIST

AIR FORCE

The Surgeon General, U. S. Department of the Air Force, Washington, D. C. 20314 (1)
Executive Officer, Director of Professional Services, Office of the Surgeon General, Hq. USAF (AFMSPA), Washington, D. C. 20314 (1)
Bioenvironmental Engineer, Hq. AFSC (SCBP), Andrews AFB, Washington, D. C. 20331 (1)
Air Force Weapons Laboratory, ATTN: WLIL (1), ATTN: WLRB-2 (1), Kirtland AFB, New Mexico 87117 (2)
Chief, Nuclear Medicine Department, P. O. Box 5088, USAF Hospital, Wright-Patterson AFB, Ohio 45433 (1)
Office of the Command Surgeon (ADCSG), Hq. ADC, USAF, Ent AFB, Colorado 80912 (1)
USAFSAM (RA), ATTN: Chief, Radiobiology Division, Brooks AFB, Texas 78235 (1)
USAFSAM, ATTN: EDAD, Brooks AFB, Texas 78235 (1)

ARMY

The Surgeon General, U. S. Department of the Army, Washington, D. C. 20314 (1)
Surgeon General, ATTN: MEDDH-N, U. S. Department of the Army, Washington, D. C. 20314 (1)
Commandant, U. S. Army Chemical Center and School, ATTN: AJMCL-T, Fort McClellan, Alabama 36201 (1)
USACDC CSSG, Doctrine Division, Fort Lee, Virginia 23801 (1)
Commanding Officer, USACDC CBR Agency, Fort McClellan, Alabama 36201 (1)
CG, USCONARC, ATTN: ATUTR-TNG (NBC), Fort Monroe, Virginia 23351 (1)
Commanding General, U. S. Army Electronics Command, ATTN: AMSEL-GG-TD, Fort Monmouth, New Jersey 07703 (1)
Office of the Chief of Engineers, ATTN: Chief, Library Branch, STINFO Division, U. S. Department of the Army, Washington, D. C. 20315 (1)
Commanding Officer, U. S. Army Mobility Equipment Research and Development Center, ATTN: Technical Documents Center, Bldg. 315, Vault, Fort Belvoir, Virginia 22060 (1)
Nuclear Branch AMCRD-DN-RE, U. S. Army Materiel Command, Washington, D. C. 20315 (1)
Commanding Officer, U. S. Army Medical Research Laboratory, Fort Knox, Kentucky 40121 (1)
Commanding Officer, USA Nuclear Medical Research Detachment, Europe, APO New York, N. Y. 09180 (2)
Army Research Office, ATTN: Chief, Scientific Analysis Branch, Life Sciences Division, 3045 Columbia Pike, Arlington, Virginia 22204 (1)
Commanding General, U. S. Army Tank-Automotive Center, ATTN: SMOTA-RCSN, Warren, Michigan 48090 (1)
Commanding Officer, U. S. Army Nuclear Defense Laboratory, ATTN: Technical Library, Edgewood Arsenal, Maryland 21010 (1)
Division of Nuclear Medicine, Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, D. C. 20012 (5)
Commanding Officer, U. S. Army Environmental Hygiene Agency, ATTN: USAEHA-RP, Edgewood Arsenal, Maryland 21010 (1)
Commandant, U. S. Army Medical Field Service School, ATTN: MEDEW-ZNW, Fort Sam Houston, Texas 78234 (1)

NAVY

Chief, Bureau of Medicine and Surgery, U. S. Navy Department, Washington, D. C. 20390 (1)
Chief, Bureau of Medicine and Surgery, ATTN: Code 71, U. S. Navy Department, Washington, D. C. 20390 (1)
Commanding Officer and Director (Code L31), U. S. Naval Civil Engineering Laboratory, Port Hueneme, California 93041 (1)
Commanding Officer, Naval Aerospace Medical Institute, Naval Aviation Medical Center, ATTN: Director of Research, Pensacola, Florida 32512 (3)
Head, Animal Behavioral Sciences Branch, Naval Aerospace Medical Institute, Naval Aerospace Medical Center, ATTN: Dr. John S. Thach, Jr., Pensacola, Florida 32512 (1)
Commanding Officer, U. S. Naval Weapons Evaluation Facility (Code WE), Kirtland Air Force Base, Albuquerque, New Mexico 87117 (1)
Commanding Officer, Nuclear Weapons Training Center, Atlantic, Nuclear Warfare Department, Norfolk, Virginia 23511 (1)

D.O.D.

Director, Defense Nuclear Agency, Washington, D. C. 20305 (1)
Director, Defense Nuclear Agency, ATTN: DDST, Washington, D. C. 20305 (1)
Director, Defense Nuclear Agency, ATTN: Chief, Medical Directorate, Washington, D. C. 20305 (4)

D.O.D. (continued)

Director, Defense Nuclear Agency, ATTN: Chief, Radiation Directorate, Washington, D. C. 20305 (1)
Director, Defense Nuclear Agency, ATTN: Technical Library (APTL), Washington, D. C. 20305 (2)
Chief, Livermore Division, FC DNA, Lawrence Radiation Laboratory, Livermore, California 94550 (1)
Commander, Headquarters Field Command, Defense Nuclear Agency, ATTN: FCTG8, Kirtland AFB, New Mexico 87117 (1)
Director, Armed Forces Institute of Pathology, Washington, D. C. 20305 (1)
Commanding Officer, Harry Diamond Laboratories, ATTN: Nuclear Vulnerability Branch, Washington, D. C. 20438 (1)
W. L. Gieseler, Harry Diamond Laboratories, Washington, D. C. 20438 (1)
Administrator, Defense Documentation Center, Cameron Station, Bldg. 5, Alexandria, Virginia 22314 (12)

OTHER GOVERNMENT

U. S. Atomic Energy Commission, Headquarters Library, Reports Section, Mail Station G-17, Washington, D. C. 20545 (1)
U. S. Atomic Energy Commission, Division of Biology and Medicine, Washington, D. C. 20545 (1)
U. S. Atomic Energy Commission, Division of Isotopes Development, ATTN: Mr. John C. Dempsey, Washington, D. C. 20545 (1)
U. S. Atomic Energy Commission, Bethesda Technical Library, 7920 Norfolk Avenue, Bethesda, Maryland 20014 (1)
U. S. Department of Commerce, Environmental Science Services Administration, ATTN: Library, Boulder Laboratories, Boulder, Colorado 80302 (1)
National Aeronautics and Space Administration, Manned Spacecraft Center, ATTN: Dr. B. D. Newsom, Code DB4, Houston, Texas 77058 (1)
National Bureau of Standards Library, ATTN: Sarah Ann Jones, Chief Librarian, Washington, D. C. 20234 (1)
National Bureau of Standards, ATTN: Chief, Radiation Physics Division, Washington, D. C. 20234 (5)
U. S. Public Health Service, Bureau of Radiological Health, Division of Biological Effects, 12720 Twinbrook Parkway, Rockville, Maryland 20852 (1)
U. S. Public Health Service, Bureau of Radiological Health, Library, 12720 Twinbrook Parkway, Rockville, Maryland 20852 (1)
U. S. Public Health Service, Northeastern Radiological Health Laboratory, 109 Holton Street, Winchester, Massachusetts 01890 (1)
U. S. Public Health Service, Southeastern Radiological Health Laboratory, P. O. Box 61, Montgomery, Alabama 36101 (1)
U. S. Public Health Service, Southwestern Radiological Health Laboratory, P. O. Box 15027, Las Vegas, Nevada 89114 (1)
Dr. C. Muelhouse, Radiation Research Center, National Bureau of Standards, Washington, D. C. 20234 (1)

OTHER

Argonne National Laboratory, Library Services Department, Report Section Bldg. 203, RM-CE-125, 9700 South Cass Avenue, Argonne, Illinois 60440 (1)
Boeing Company Aerospace Library, ATTN: 8K-38 Ruth E. Peerenboom, P.O. Box 3999, Seattle, Washington 98124 (2)
Dr. J. T. Brennan, Radiology Department, University of Pennsylvania, 3400 Spruce Street, Philadelphia, Pennsylvania 19104 (1)
Brookhaven National Laboratory, Information Division, ATTN: Research Library, Upton, Long Island, New York 11973 (2)
Dr. J. S. Burkle, Director of Nuclear Medicine, York Hospital, York, Pennsylvania 17403 (1)
S. C. Bushong, Department of Radiology, Baylor University College of Medicine, Houston, Texas 77024 (1)
University of California, Department of Nuclear Engineering, Berkeley, California 94720 (1)
Director, Radiobiology Laboratory, University of California, Davis, California 95616 (1)
University of California, Lawrence Radiation Laboratory, Technical Information Division Library L-3, P.O. Box 808, Livermore, California 94551 (2)
University of California, Laboratory of Nuclear Medicine and Radiation Biology, Library; 900 Veteran Avenue, Los Angeles, California 90024 (1)
Cdr. William H. Chapman, USN (Ret.), Bio-Medical Division L-523, Lawrence Radiation Laboratory, University of California, P. O. Box 808, Livermore, California 94551 (1)
Cornell University, Department of Nuclear Engineering, Ithaca, New York 14850 (1)
Dr. L. W. Davis, Radiology Department, University of Pennsylvania, 3400 Spruce Street, Philadelphia, Pennsylvania 19104 (1)
Professor R. Duffey, Department of Nuclear Engineering, University of Maryland, College Park, Maryland 20740 (1)

OTHER (continued)

E. I. du Pont de Nemours and Company, Savannah River Laboratory, Technical Information Service 773-A, Aiken, South Carolina 29801 (1)
Professor Merril Eisenbud, New York University, Tuxedo, New York 10987 (1)
Dr. T. C. Evans, Radiation Research Laboratory, College of Medicine, University of Iowa, Iowa City, Iowa 52240 (1)
Dr. Arnold Feldman, Institute of Radiology, School of Medicine, Washington University, 510 South Kingshighway, St. Louis, Missouri 63110 (1)
Mr. Orin Gelderloos, Division of Literature, University of Michigan, Dearborn Campus, Dearborn, Michigan 48124 (1)
General Dynamics/Fort Worth, ATTN: Librarian, P. O. Box 748, Fort Worth, Texas 76101 (1)
Gulf General Atomic Incorporated, ATTN: A. Graf, P. O. Box 608, San Diego, California 92112 (1)
Gulf General Atomic Incorporated, ATTN: Library, P. O. Box 608, San Diego, California 92112 (1)
Holmes and Narver, Inc., Nuclear Division Library, 828 South Figueroa Street, Los Angeles, California 90017 (1)
IIT Research Institute, ATTN: Document Library, 10 West 35th Street, Chicago, Illinois 60616 (1)
Professor E. Jordan, Department of Nuclear Engineering, Catholic University, Washington, D. C. 20017 (1)
Los Alamos Scientific Laboratory, ATTN: Report Librarian, P. O. Box 1663, Los Alamos, New Mexico 87544 (1)
Director, Nuclear Science Center, Louisiana State University, Baton Rouge, Louisiana 70803 (2)
Lovelace Foundation for Medical Education and Research, Document Library, 5200 Gibson Boulevard, S. E., Albuquerque, New Mexico 87108 (1)
Dr. J. I. Marcum, Rand Corporation, 1700 Main Street, Santa Monica, California 90401 (1)
Massachusetts Institute of Technology, M.I.T. Libraries, Technical Reports, Room 14 E-210, Cambridge, Massachusetts 02139 (1)
Dr. Charles W. Mays, Physics Group Leader, Radiobiology Division, University of Utah, Salt Lake City, Utah 84112 (1)
Dr. R. L. Murray, Department of Nuclear Engineering, North Carolina State University, Raleigh, N. C. 27607 (1)
New York University, Department of Nuclear Engineering, New York, N. Y. 10019 (1)
President, Nuclear Technology Corporation, 116 Main Street, White Plains, New York 10601 (1)
Ohio State University, Nuclear Reactor Laboratory, 1298 Kinnear Road, Columbus, Ohio 43212 (1)
Dr. Alan Orvis, Consultant in Biophysics, Mayo Clinic, Rochester, Minnesota 55901 (1)
Pennsylvania State University, Department of Nuclear Engineering, University Park, Pennsylvania 16802 (1)
Purdue University, Nuclear Engineering Library, Lafayette, Indiana 47909 (1)
Radiation Effects Information Center, Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio 43201 (1)
Dr. S. M. Reichard, Director, Division of Radiobiology, Medical College of Georgia, Augusta, Georgia 30902 (1)
Dr. H. H. Rossi, 630 West 168th Street, New York, N. Y. 10032 (1)
Dr. Eugene L. Saenger, Director, Radioisotope Laboratory, Cincinnati General Hospital, Cincinnati, Ohio 45229 (1)
Sandia Corporation Library, P. O. Box 5800, Albuquerque, New Mexico 87115 (1)
Sandia Corporation, Livermore Laboratory, ATTN: Technical Library, P. O. Box 969, Livermore, California 94550 (1)
Scope Publications, Franklin Station, P. O. Box 7407, Washington, D. C. 20004 (1)
Texas A and M College, Department of Nuclear Engineering, College Station, Texas 77843 (1)
Texas A and M University, Radiation Biology Laboratory, Texas Engineering Experiment Station, College Station, Texas 77840 (2)
Texas Nuclear Corporation, ATTN: Director of Research, Box 9267 Allandale Station, Austin, Texas 78756 (1)
University of Arizona, Department of Nuclear Engineering, Tucson, Arizona 85721 (1)
University of Rochester, Atomic Energy Project Library, P. O. Box 287, Station 3, Rochester, N. Y. 14620 (1)
University of Southern California, Nuclear Physics Laboratory, University Park, Los Angeles, California 90007 (1)
Western Reserve University, Department of Radiology, Division of Radiation Biology, Cleveland, Ohio 44106 (1)
Professor M. E. Wyman, Nuclear Engineering Program, University of Illinois, Urbana, Illinois 61801 (1)
Director, Electron Acccelerator Laboratory, Yale University, New Haven, Connecticut 06520 (1)
Mr. Lionel Zamore, 601 Brightwater Court, Brooklyn, New York 11235 (1)

FOREIGN

International Atomic Energy Agency, Kärntnerring 11, Vienna I. 1010, Austria (1)
European Atomic Energy Community, C. E. E. A., Library, 51 rue Belliard, Brussels 4, Belgium (1)
Library, Atomic Energy of Canada Ltd., P. O. Box 905, Toronto 18, Ontario, Canada (1)
University of Saskatchewan, ATTN: Director, Accelerator Laboratory, Saskatoon, Saskatchewan, Canada (1)
Director, Science Abstracts, Institution of Electrical Engineers, Savoy Place, London WC2, England (1)
Dr. L. G. Lajtha, Paterson Laboratories, Christie Hospital and Holt Radium Institute, Manchester, England (1)
Dr. L. F. Lamerton, Biophysics Department, Institute of Cancer Research, Surrey Branch, Belmont, Sutton, Surrey, England (1)

FOREIGN (continued)

Dr. G. E. Adams, Research Unit in Radiobiology, Mount Vernon Hospital, Northwood, Middlesex, England (1)
National Lending Library for Science and Technology, Boston Spa, Yorkshire, England (1)
Directorate of Medical and Health Services, FAF (Federal Armed Forces), Bonn, Ermekeilstrasse 27, West Germany (1)
Abteilung für Strahlenbiologie im Institut für Biophysik der Universität Bonn, 53 Bonn-Venusberg, Annaberger Weg 15, Federal Republic of Germany (2)
Prof. Dr. H. Langendorff, Direktor des Radiologischen Instituts der Universität, 78 Freiburg im Breisgau, Albertstrasse 23, Germany (1)
Priv.- Doz. Dr. O. Messerschmidt, Radiologisches Institut der Universität, 78 Freiburg im Breisgau, Albertstrasse 23, Germany (1)
Dr. Helmut Mitschrich, Sanitätsamt der Bundeswehr, 53 Bonn-Beuel, Zingsheimstrasse 5, Germany (2)
Prof. Dr. F. Wachsmann, Gesellschaft für Strahlenforschung m.b.H., 8042 Neuherberg bei München, Institut für Strahlenschutz, Ingolstadter Landstrasse 1, München, Germany (1)
Col. Joachim Emde, Direktor, Spezialstab ATV, ABC- und Selbstschutzschule, 8972 Sonthofen 2/Allgäu, Berghoferstrasse 17, West Germany (1)
Dr. G. W. Barendsen, Radiobiological Institute TNO, Rijswijk, Netherlands (1)
Puerto Rico Nuclear Center, ATTN: Reading Room, College Station, Mayaguez, Puerto Rico 00708 (2)

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Armed Forces Radiobiology Research Institute Defense Nuclear Agency Bethesda, Maryland 20014	UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE

REACTOR DOSIMETRY WITH PAIRED MINIATURE IONIZATION CHAMBERS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

D. W. Shosa

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1971	17	12

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. NWER XAXM	AFRRI TN71-7
c. Task and Subtask D 908	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d. Work Unit 04	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Director Defense Nuclear Agency Washington, D. C. 20305

13. ABSTRACT

Paired ionization chambers with nominal volumes of 0.05 cm^3 are in use at the Armed Forces Radiobiology Research Institute to measure neutron and gamma components of depth doses in steady-state and pulsed TRIGA fields. Cavity chamber theory is employed to obtain quantitative estimates of neutron and gamma dose sensitivities of a chamber with a tissue-equivalent plastic wall filled with a tissue-equivalent gas and a magnesium chamber filled with CO_2. The uncertainties in these estimates have been propagated through the paired chamber equations and result in the following uncertainties in measured dose components in a field where the neutron to gamma dose ratio varies from 0.1 to 15

Total dose	± 8 percent	
Gamma dose	± 20 percent ($N/\Gamma \lesssim 0.1$)	to ± 30 percent ($N/\Gamma \gtrsim 10$)
Neutron dose	± 8 percent ($N/\Gamma \gtrsim 10$)	to ± 12 percent ($N/\Gamma \sim 0.1$).

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT